Glider-based Passive Acoustic Monitoring Techniques in the Southern California Region

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LONG-TERM GOALS

Glider-based monitoring may contribute to Navy environmental compliance, as well as to basic scientific studies of marine mammals. Autonomous glider-based passive acoustic monitoring of marine mammal presence is particularly needed within the southern California offshore region, the site of significant naval training. We aim to create an operational system that provides timely information on marine mammal presence to support Naval mitigation efforts in the southern California region.

OBJECTIVES

Our objective is to develop and test glider capabilities for marine mammal call detection and classification. Gliders provide platforms for acoustic monitoring over extended periods of time (weeks to months), with significant processing capabilities for detection, classification and localization of marine mammal calls. For gliders to be effective in this role, new algorithms for automated detection and classification of marine mammal calls are needed. In addition, we will test different glider platforms (submerged versus surface) for marine mammal call detection capabilities.

APPROACH

We are exploring two glider platforms with expanded capabilities for real-time, persistent, passive acoustic monitoring: (1) the flying wing ZRay glider and (2) the Wave glider. The ZRay is the world's largest underwater glider, employing a high lift-to-drag ratio wing design allowing efficient long distance travel at higher speeds and with greater payloads than traditional profiling gliders. The Wave glider has a surface float connected by cable to a submerged glider, using wave action for propulsion.

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The presence of the Wave Glider surface float, which includes Iridium data communications, allows for real-time notification of marine mammal presence.

We have put together a collaborative team to investigate the ZRay and Wave Glider capabilities for marine mammal monitoring. Gerald D'Spain is responsible for ZRay glider development and integration with marine mammal detection capabilities. John Hildebrand and Sean Wiggins are responsible for wave glider-based development of marine mammal recording and detection hardware and software. Marie Roch is responsible for development of hardware and algorithms for real-time marine mammal detection, as well as marine mammal call database software.

A range validation test is scheduled for November 2010 to compare multiple gliders against the southern California SCORE naval range installed hydrophones for detection and classification of marine mammal calls. Glider operations will be conducted simultaneously with the monitoring of range hydrophones by the M3R system (Dave Moretti, NUWC).

WORK COMPLETED

Wave Glider and HARP Integration

The High-frequency Acoustic Recording Package (HARP) data logging system (Wiggins and Hildebrand, 2007) was re-packaged into the larger (forward) dry boxes on the surface vehicle of the Wave Glider (Willcox et al., 2009). The HARP system includes low-power electronics (1/2W continuous data acquisition / 3W 20% duty cycle data storage), high-speed data sampling (200 kHz, 16-bit), and 16 laptop disk drives (2TB) for data storage. A hydrophone was designed to be towed behind the Wave Glider and to have a small cross-sectional area (1" diameter) with a small diameter (0.25") electro-mechanical cable to minimize drag while towing. The hydrophone consists of two transducers: Benthos AQ-1 cartridge for 10Hz- 2kHz and Sonar Research HS-150 for 2kHz-100kHz. These two sensors are amplified and filtered with electronics inside the oil-filled hydrophone tube. The conditioned analog signals are digitized and stored to disk by they HARP data logger. The hydrophone cable was 10m long and was attached to the wing glider system, approximately 8m beneath the surface vehicle. The Wave Glider with HARP was deployed on multiple tests, both in the Liquid Robotics test range offshore of Puako Beach, Hawai'i and from the SIO Pier in La Jolla, California.

ZRay Development

Final design and construction of ZRay, the next generation flying wing underwater glider, was completed in summer, 2010. Figure 1 shows a photograph of this new glider. The outer shroud is made of ABS plastic and is mounted to a titanium inner strength structure. All subsystems required for the glider's fully autonomous flight also are mounted to this internal strength structure. This structure with internal subsystems was taken to sea in March, 2010, to conduct tests at various depths up to the maximum design depth of 300 m. All systems performed flawlessly. Subsequently, trim, ballasting and additional subsystem testing with the fully constructed ZRay were completed in a saltwater tank. The glider is ready for its first flights at sea.

Figure 1. Photograph of ZRay, suspended from its three lift points in the laboratory without its 3-ft antenna mast or wing tips installed.

ZRay carries a variety of passive acoustic sensor systems along with associated real-time detection, classification, and localization hardware and software to perform real-time monitoring across a wide range of marine mammal species. Inside a sonar dome all along the wing's leading edge is a 27-channel hydrophone array with 15 kHz per channel bandwidth. This array permits high-spatial-resolution localization of low frequency sounds including mysticete vocalizations and man-made sounds such as surface ships and active sonar. A single board computer running a real-time localization, detection, and classification algorithm suite designed for humpback whales has been connected this past year to the output from this hydrophone array. The output from the four channels of a low-frequency acoustic vector sensor, installed in the outer portion of the port-side wing, are connected to the hydrophone array's data acquisition system, in a record-only mode.

RESULTS

Real-time Detection and Classification

The real-time detection and classification algorithms have been completed and integration testing between the echolocation click processor unit and the mini-HARP is underway. The algorithm has been regression tested in an off-line mode against a five-species subset of a previously studied towed-array and dipping hydrophone dataset (Roch et al. in press). The testing methodology used multiple runs of a random-sampling strategy that prevents splitting data from a sighting across the train and test boundaries.

A mean species identification error of .26 with standard deviation σ=.13 was obtained from 100 three-fold trials. This is in contrast with a non real-time method on the same data subset which exhibited an error rate of .24$\pm$.12σ. The .24 mean error lies within a 95% confidence interval for means of between .22 and .30 as determined by the normal distribution approximation method (Huang et al. 2001). In addition to stochastic variation, differences may be attributable to additional steps in the non real-time algorithm which include pruning of echosounders, a two stage click detection algorithm which verifies

click-like spectral properties of short segments of data, and suppression of closely spaced clicks as probable echoes.

IMPACT/APPLICATIONS

Existing underwater gliders (Seaglider, Spray, and Slocum) are highly successful underwater platforms for collecting vertical profiles of water column properties to provide near real-time environmental characterization. However, they were not designed to carry wide-band or multi-channel passive acoustic systems. The ZRay flying wing underwater gliders and the Wave Glider are capable of carrying large and high-data-rate payloads, have sufficient physical size to provide large array aperture at low and mid frequencies, and at the same time minimize onboard energy consumed in horizontal transport. These gliders have the best potential future impact for science and/or systems applications for marine mammal studies and monitoring.

RELATED PROJECTS

Project title: Southern California Marine Mammal Studies; John Hildebrand, Principal Investigator. Sponsor: CNO N45 and the Naval Postgraduate School; Support from this project allowed for collection of the acoustic data used to create the southern California marine mammal call database.

Project title: Passive acoustic monitoring for the detection and identification of marine mammals, Marie A. Roch Principal Investigator. ONR Grant: N000140811199. This project aided in the development of algorithms for marine mammal detection and classification.

Project title: Flying wing underwater glider for persistent surveillance missions, Gerald L. D'Spain Principal Investigator. ONR Grant: N000140410558. This project supported development of large autonomous underwater gliders based on the flying wing design.

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